ASSESSMENT OF THE PACIFIC COD STOCK IN THE EASTERN BERING SEA AND ALEUTIAN ISLANDS AREA

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EXECUTIVE SUMMARY

Summary of Major Changes

Relative to the November edition of last year's BSAI SAFE report, the following substantive changes have been made in the Pacific cod stock assessment.

Changes in the Input Data

1) Size composition data from the 1997 and January-August 1998 commercial fisheries were incorporated into the model.
2) Size composition data from the 1998 EBS bottom trawl survey were incorporated.
3) The biomass estimate from the 1998 EBS bottom trawl survey was incorporated.

Changes in the Assessment Model

There were no changes in the assessment model this year.

Changes in Assessment Results

1) The projected 1999 total age 3+ biomass for the BSAI is 1,210,000 t, down about 10% from last year's projection for biomass in 1998 and up about 3% from last year's $F_{40\%}$ projection for biomass in 1999.
2) With survey catchability Q and natural mortality M fixed at the conventional values of 1.00 and 0.37, the maximum permissible 1999 ABC for the BSAI is 196,000 t, down about 7% from last year's recommendation for 1998 and down about 4% from last year's $F_{40\%}$ projection for 1999. When uncertainty in Q and M is considered, the risk-averse optimum ABC for 1999 is 177,000 t.
3) The projected 1999 overfishing level for the BSAI is 264,000 t, down about 21% from last year's projection for 1998 and up about 3% from last year's $F_{30\%}$ projection for 1999.

Responses to Comments of the Scientific and Statistical Committee (SSC)

SSC Comments Specific to the Pacific Cod Assessments

From the December, 1997 minutes: *"The SSC encourages continued research and refinement of model processes and evaluation of parameter uncertainty."* Continued research, refinement, and evaluation along the lines suggested by the SSC is described under the headings "Analytic Approach" and "Model Evaluation."

From the October, 1998 minutes: *"The SSC asks the assessment scientist to consider alternative resolutions to the divergence between the prior and likelihood. For example, the ABC calculated under the prior and likelihood model might be calculated separately then averaged, with the separate estimates providing a range."* The SSC's suggested method for calculating ABC is implemented under the heading "ABC Recommendation."

From the October, 1998 minutes: *"In particular the SSC would suggest a plan for analysis of the length-frequency samples used in the catch-at-age calculations be developed.... The sampling might be looked at with respect to a number of factors, in particular the influence of sample size, stratification by fleet sector (gear), time of year and fishing location (statistical area). Is the sampling program adequate? If more fish cannot be measured, should more but smaller samples be taken? Does the spread of samples among the gear-month-area strata lead to biasing the results of the model? What distinctions between the GOA and BSAI suggest different sampling needs for the two areas? How are State of Alaska samples in the GOA entered into the model?"* There has not been sufficient time since the October SSC meeting to develop a plan for analysis of the length-frequency samples used in the catch-at-age calculations. However, as a first step in such an analysis, sample sizes have been tabulated with respect to year, time period, and commercial gear type in Table 2.6; with respect to time period, commercial gear type, and statistical area for the four most recent years in Tables 2.7, 2.8, 2.9, and 2.10; with respect to year, time period, and size bin for three commercial gear types in Tables 2.11, 2.12, and 2.13; and with respect to year and size bin for the trawl survey in Table 2.14. Sample sizes are discussed under the heading "Commercial Catch Data."

SSC Comments on Assessments in General

The December, 1997 and October, 1998 minutes contain no comments on assessments in general.

INTRODUCTION

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34E N latitude, with a northern limit of about 63E N latitude. Pacific cod is distributed widely over the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. The resource in these two areas (BSAI) is managed as a single unit. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (GOA), and genetic studies (e.g., Grant et al. 1987) have failed to show significant evidence of stock structure within these areas. Pacific cod is not known to exhibit any special life history characteristics that would require it to be assessed or managed differently from other groundfish stocks in the EBS or AI areas.

FISHERY

During the early 1960s, a Japanese longline fishery harvested BSAI Pacific cod for the frozen fish market. Beginning in 1964, the Japanese trawl fishery for walleye pollock (*Theragra chalcogramma*) expanded and cod became an important bycatch species and an occasional target species when high concentrations were detected during pollock operations. By the time that the Magnuson Fishery Conservation and Management Act went into effect in 1977, foreign catches of Pacific cod had consistently been in the 30,000-70,000 t range for a full decade. Catches of Pacific cod since 1978 are shown in Table 2.1, broken down by management area, year, fleet sector, and gear type. In 1981, a U.S. domestic trawl fishery and several joint venture fisheries began operations in the BSAI. The foreign and joint venture sectors dominated catches through 1988, but by 1989 the domestic sector was dominant and by 1991 the foreign and joint venture sectors had been displaced entirely. Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components.

The history of acceptable biological catch (ABC) and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate (i.e., all-gear, combined area) commercial catches in Table 2.2. From 1980 through 1998, TAC averaged about 74% of ABC, and aggregate commercial catch averaged about 84% of TAC. In 5 of these 19 years (26%), TAC equaled ABC exactly, and in 4 of these 19 years (21%), catch exceeded TAC. Changes in ABC over time are typically attributable to three factors: 1) changes in resource abundance, 2) changes in management strategy, and 3) changes in the stock assessment model. For example, from 1980 through 1998, five different assessment models were used (Table 2.2).

Historically, the great majority of the BSAI catch has come from the EBS area. During the most recent five-year period (1993-1997), the EBS accounted for an average of about 87% of the BSAI catch. The distribution of federally observed hauls or sets in the BSAI and GOA is shown for the 1997 trawl, longline, and pot fisheries for Pacific cod in Figures 2.1, 2.2, and 2.3, respectively.

The catches shown in Tables 2.1 and 2.2 include estimated discards. Recent (1996) discard rates are summarized in Tables 2.3 and 2.4. Table 2.3 shows species discards in the 1996 Pacific cod fisheries, expressed as percentages of the total catch of all species in those fisheries. Table 2.4 shows discards of Pacific cod in the 1996 fisheries, expressed as percentages of the total area-wide Pacific cod catch. In the eastern Bering Sea, the species with the highest discard rate in the 1996 Pacific cod fisheries was walleye pollock in the trawl fishery. In the Aleutian Islands area, the species with the highest discard rate in the

1996 Pacific cod fisheries was Pacific cod itself in the longline fishery. In the eastern Bering Sea, the fishery with the highest discard rate of Pacific cod was the midwater trawl fishery for walleye pollock. In the Aleutian Islands, the fishery with the highest discard rate of Pacific cod was the trawl fishery for Atka mackerel (*Pleurogrammus monopterygius*).

DATA

This section describes data used in the current assessment. It does not attempt to summarize all available data pertaining to Pacific cod in the BSAI.

Commercial Catch Data

Catch Biomass

Catches (including estimated discards) taken in the EBS since 1978 are shown in Table 2.5, broken down by the three main gear types and the following within-year time intervals, or "periods": January-May, June-August, and September-December. This particular division, which was suggested by participants in the EBS fishery, is intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning period may be different than at other times of year). In years for which estimates of the distribution by gear or period were not available, proxies based on other years' distributions were used.

Catch Size Composition

Fishery size compositions are presently available, by gear, for the years 1978 through the first part of 1998. As in last year's assessment, size composition data from trawl catches sampled on shore were not included in the set of input data, because a comparison of cruises for which both at-sea and shoreside size composition samples were available showed that, in the case of trawl catches, the shoreside data typically contained a smaller proportion of small fish than the at-sea data, indicating that these data may reflect post-discard landings rather than the entire catch. For ease of representation and analysis, length frequency data for Pacific cod can usefully be grouped according to the following set of 25 intervals, or "bins," with the upper and lower boundaries shown in cm:

Bin Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Lower Bound:	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
Upper Bound:	11	14	17	20	23	26	29	32	35	38	41	44	49	54	59	64	69	74	79	84	89	94	99	104	115

The total sample sizes for each year, gear, and period are shown in Table 2.6. The SSC has requested that sample sizes also be broken down by statistical area. The sample sizes shown in Table 2.6 for the years 1994, 1995, 1996, and 1997 are therefore subdivided by statistical area in Tables 2.7, 2.8, 2.9, and 2.10, respectively (differences between total sample sizes shown in Table 2.6 and the area-partitioned tables may be attributed to the fact that the data used in the former were retrieved on a different date than the data used in the latter and the fact that shore-side observations of trawl size compostions are incuded in the area-partioned tables). Boundaries of the statistical areas referenced in these tables are illustrated in Figure 2.4. It is possible that the distribution of length samples may change in the near future due to a modification of the observer sampling protocol. In general, the modifications are expected to result in fewer cod being measured but a more evenly distributed sample overall (the goal is to obtain lengths from 20 fish of the predominant groundfish species in each sampled haul).

The collections of relative length frequencies are shown, by year, period, and size bin for the trawl fishery in Table 2.11, the longline fishery in Table 2.12, and the pot fishery in Table 2.13.

Trawl Survey Data

EBS Shelf Survey

The relative size compositions from trawl surveys of the EBS shelf conducted by the Alaska Fisheries Science Center since 1979 are shown in Table 2.14, using the same length bins defined above for the commercial catch size compositions. Information regarding the absolute numbers of fish measured at each length are available only for the years 1986-1987 and 1990-1998. For all other years, only relative numbers of measured fish are available. The total sample sizes from the years 1986-1987 and 1990-1998 are shown below:

Year:	1986	1987	1990	1991	1992	1993	1994	1995	1996	1997	1998
Sample size:	15376	10609	5628	7228	9601	10404	13922	9216	9348	9169	9583

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.15, together with the standard errors and upper and lower 95% confidence intervals (CI) for the biomass estimates. Survey results indicate that biomass increased steadily from 1978 through 1983, then remained relatively constant from 1983 through 1989. The highest biomass ever observed by the survey was the 1994 estimate of 1,368,109 t. Since then, the survey biomass estimate has declined each year. This year's survey estimate nearly replaced the 1991 biomass estimate as the lowest in the time series.

In terms of numbers (as opposed to biomass), the record high was observed in 1979, when the population was estimated to include over 1.5 billion fish. The 1994 estimate of population numbers was the second highest on record. After the peak in 1994, numerical declines were observed in 1995, 1996, and 1997, paralleling the biomass time trend. However, this year the trend reversed, with the 1998 survey estimate of population numbers increasing by 6% relative to the 1997 estimate.

Aleutian Trawl Survey

Biomass estimates for the Aleutian Islands region were derived from U.S.-Japan cooperative trawl surveys conducted during the summers of 1980, 1983, and 1986, and by U.S. trawl surveys of the same area in 1991, 1994, and 1997. These surveys covered both the Aleutian management area (170 degrees east to 170 degrees west) and a portion of the EBS ("Bering Sea Area I") not covered by the EBS shelf surveys. The time series of biomass estimates from both portions of the Aleutian survey area are shown together with their sum below (all figures are in t):

Year	Aleutian Management Area	Bering Sea Area I	Aleutian Survey Area
1980	52,070	74,373	126,443
1983	113,148	45,624	158,772
1986	172,625	42,298	214,923
1991	163,029	12,403	175,432
1994	148,435	46,945	195,380
1997	74,675	15,109	89,784

As in previous assessments of Pacific cod in the BSAI, a weighted average formed from EBS and Aleutian survey biomass estimates is used in the present assessment to provide a conversion factor which can be used to translate model projections of EBS catch and biomass into BSAI equivalents. Because the assessment model is configured to represent the portion of the Pacific cod population inhabiting the EBS survey area (as opposed to the more extensive EBS *management* area), it seems appropriate to use the biomass estimates from the entire Aleutian survey area (as opposed to the less extensive Aleutian *management* area) to inflate model projections of EBS catch and biomass. Weighted averages of the biomass estimates from the entire Aleutian survey area and their EBS survey area counterparts indicate that, on average, approximately six-sevenths (6/7) of the BSAI Pacific cod biomass resides in the EBS survey area. Thus, to inflate model projections of EBS catch and biomass to a BSAI-wide total, a multiplier of about 7/6 is appropriate.

Length at Age, Weight at Length, and Maturity at Length

Length at age data are few for BSAI Pacific cod and are used only sparingly in this assessment. The otoliths examined from fish sampled during EBS shelf trawl surveys provide the following data regarding the relationship between age and length and the amount of spread around that relationship (lengths, in cm, were measured during summer, and ages are back-dated to January 1):

Age group:	1	2	3	4	5	6	7	8	9	10	11	12
Average length:	19	29	37	48	57	65	73	79	82	84	86	89
St. dev. of length:	3.5	5.3	5.0	4.9	4.2	3.7	4.0	5.4	7.4	5.8	7.4	7.7

Weight measurements taken by observers over a number of years in the BSAI fishery yield the following data regarding average weights (in kg) at length, grouped according to size composition bin (as defined under "Catch Size Composition" above):

Bin number:	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Ave. weight:	0.5	0.7	0.8	1.0	1.4	1.6	2.2	2.8	3.7	4.8	5.7	7.0	8.5	9.9	11.5	13.6	15.9

During this year's EBS trawl survey an additional 365 weights were recorded. These new data were not received in time to be incorporated into this year's stock assessment. However, preliminary examination of the new data indicate a weight-length relationship fairly similar to the above.

From 1984 through 1994, assessments of EBS Pacific cod used a maturity schedule based on a logistic function with an inflection at about 61 cm. This schedule was based on a survey sample of fish taken during the 1981-1982 field seasons (see review provided by Thompson and Methot 1993). To update the maturity schedule for Pacific cod, a sampling program was initiated in 1993, using commercial fishery observers. So far, data have been analyzed for 1994 only. These data consist of observers' visual determinations regarding the spawning condition of 2312 females taken in the EBS fishery. Of these 2312 females, 231 were smaller than 42 cm (the lower boundary of length bin 12). None of these sub-42 cm fish were mature. The observed proportions of mature fish in the remaining length bins, together with the numbers of fish sampled in those length bins, are shown below (bins are defined under "Catch Size Composition" above):

Bin number:	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Prop. mature:	0.03	0.05	0.14	0.19	0.28	0.53	0.69	0.82	0.89	0.94	0.94	0.91	0.89	1.00
Sample size:	39	122	226	313	295	300	320	177	103	70	50	35	19	12

ANALYTIC APPROACH

Model Structure

This year's model structure is identical to the one used in the previous two assessments (Thompson and Dorn 1996, 1997). Beginning with the 1993 SAFE report (Thompson and Methot 1993), a length-structured Synthesis model (Methot 1986, 1989, 1990, 1998) has formed the primary analytical tool used to assess the EBS Pacific cod stock. Synthesis is a program that uses the parameters of a set of equations governing the assumed dynamics of the stock (the "model parameters") as surrogates for the parameters of statistical distributions from which the data are assumed to be drawn (the "distribution parameters"), and varies the model parameters systematically in the direction of increasing likelihood until a maximum is reached. The overall likelihood is the product of the likelihoods for each of the model components. Each likelihood component is associated with a set of data assumed to be drawn from statistical distributions of the same general form (e.g., multinomial, lognormal, etc.). Typically, likelihood components are associated with data sets such as catch size (or age) composition, survey size (or age) composition, and survey biomass.

Symbols used in the stock assessment model are listed in Table 2.16 (note that this list applies to the stock assessment model only, and does not include all symbols used in the "Projections and Harvest Alternatives" section of this assessment). Synthesis uses a total of 16 dimensional constants, special values of indices, and special values of continuous variables, all of which are listed on the first page of Table 2.16. The values of these quantities are not estimated statistically, in the strict sense, but are typically set by assumption or as a matter of structural specification. The values of these constants, indices, and variables are listed in Table 2.17, with a brief rationale given for each value used. In contrast to the quantities whose values are specified in Table 2.17, Synthesis uses a large number of parameters that are estimated statistically (though the estimation itself may not necessarily take place within Synthesis). For ease of reference, capital Roman letters are used to designate such "Synthesis parameters," which are listed on the second page of Table 2.16.

Functional representations of population dynamics are given in the Appendix, using the symbols defined on the first two pages of Table 2.16. It should be noted that, while the equations given in the Appendix are generally similar to those used in Synthesis, they may differ in detail. Also, only a subset of the equations actually used by Synthesis is shown. Basically, enough equations are shown to illustrate at least one use for each of the symbols shown on the first two pages of Table 2.16.

As in previous assessments, the present assessment uses Bayesian methods to address uncertainty surrounding the true values of model parameters. Unfortunately, as presently configured, Synthesis is not equipped to handle a full Bayesian analysis. Therefore, a type of meta-analysis is used to implement the Bayesian portion of this assessment (the term "meta-analysis" is used here to denote the fact that this analysis is performed on results obtained from a set of related but technically independent and self-contained primary analyses). The Bayesian meta-analysis exploits the fact that it is sometimes possible (e.g., Walters and Ludwig 1994) to obtain an approximate Bayesian solution by profiling over some subset of the complete parameter set, with all other parameters fixed at their conditional maximum likelihood values (conditional, that is, on the parameter values being considered at any given point in the profile). Although it represents an extreme simplification, the approach used here was to consider the uncertainty surrounding two parameters only, specifically the natural mortality rate M and the survey catchability Q. The Bayesian meta-analysis, which uses the set of parameters shown on the third page of Table 2.16, proceeds as follows:

1) Assume a bivariate normal prior distribution for M and Q.

2) Create a large number (thousands) of individual Synthesis models, each based on a unique pair of M and Q values and each resulting in a conditional maximum log-likelihood and a conditional 1999 ABC (i.e., a conditional 1999 harvest under some specified harvest strategy).

3) Smooth the bivariate log-likelihood profile by regressing a sample of conditional maximum log-likelihood values against M and Q, assuming a bivariate quadratic relationship. (Even with the simplification afforded by limiting the analysis to uncertainty in M and Q only, describing the likelihood profile is an extremely difficult task. A requirement for the analysis' success is the ability to determine the maximum value of the log-likelihood function at each combination of M and Q values included in the profile. However, the log-likelihood function at many, if not all, combinations of M and Q values can be either very flat or very "ripply," meaning that it is often difficult to be confident that an *apparent* maximum is the *true* maximum. The smoothing procedure was undertaken in an effort to mitigate these problems.)

4) Add an appropriate constant to the smoothed log-likelihood profile so as to result in a rescaled likelihood profile which is proportional to a bivariate normal distribution.

5) Multiply the prior distribution by the rescaled likelihood, then rescale again to yield a bivariate normal posterior distribution.

6) Smooth the bivariate log-ABC profile by regressing a sample of conditional log-ABC values against M and Q, assuming a bivariate quadratic relationship. (The reasons for smoothing the log-ABC profile are the same as given above in Step 3.)

7) Multiply the posterior distribution by the smoothed log-ABC profile, integrate with respect to M and Q, then take the antilogarithm of the result to obtain the geometric mean ABC.

The Bayesian meta-analysis provides a context within which the results of any of the thousands of individual Synthesis models described in Step 2 may be viewed. To keep the number of alternative models manageable, however, only three models will be focused upon in the present assessment: Model 1 sets M and Q equal to the best point estimates that can be obtained independently of the Synthesis models used in the present assessment, estimates which are also used to define the means of the marginal prior distributions for these two parameters. Model 2 sets M and Q equal to their maximum likelihood estimates. Model 3 sets M and Q equal to the means of their marginal posterior distributions.

Parameters Estimated Independently

Table 2.18 divides the set of Synthesis parameters into two parts, the first of which lists those parameters that were estimated independently (i.e., outside of Synthesis), and the second of which lists those parameters that were estimated conditionally (i.e., inside of Synthesis). This section describes the estimation of parameters in the first part of Table 2.18.

Natural Mortality

For Model 1, the natural mortality rate was estimated independently of other parameters at a value of 0.37. This value was used in the present assessment for the following reasons: 1) it was derived as the maximum likelihood estimate of M in the 1993 BSAI Pacific cod assessment, 2) it has been used to represent M in all BSAI Pacific cod assessments since 1993 and in all GOA Pacific cod assessments except one since 1994, 3) it was explicitly accepted by the SSC for use as an estimate of M in the GOA Pacific cod assessment (December 1994 SSC minutes, item D-3(b)), and 4) it lies well within the range of previously published estimates of M shown below:

Area	Author	Year	Value
Eastern Bering Sea	Low	1974	0.30-0.45
	Wespestad et al.	1982	0.70
	Bakkala and Wespestad	1985	0.45
	Thompson and Shimada	1990	0.29
	Thompson and Methot	1993	0.37
Gulf of Alaska	Thompson and Zenger	1993	0.27
	Thompson and Zenger	1995	0.50
British Columbia	Ketchen	1964	0.83-0.99
	Fournier	1983	0.65

For Models 2 and 3, the natural mortality rate was not an independently estimated parameter.

Trawl Survey Catchability

For Model 1, the trawl survey catchability coefficient was estimated independently of other parameters at a value of 1.0. This value was used in the present assessment mostly because it had been used in all previous assessments. Also, preliminary results of recent experimental work conducted by the Alaska Fisheries Science Center's Resource Assessment and Conservation Engineering Division tend to confirm that this is a reasonable value (David Somerton, pers. commun.). For Models 2 and 3, the trawl survey catchability coefficient was not an independently estimated parameter.

Weight at Length

Parameters (Table 2.16) governing the relationship between weight and length (Appendix) were estimated by regression from the available data (see "Data" above), giving the following values (weights are in kg, lengths in cm): $W_1 = 5.29 \times 10^{-6}$, $W_2 = 3.206$.

Length at First Age of Survey Observation

Assuming that the first age at which Pacific cod are seen in the trawl survey (a_1) is approximately 1.5 years, the length at this age (L_1) was estimated to be 18.2 cm by averaging the lengths corresponding to the first mode greater than 14 cm (bin 2) from each of the five most recent survey size compositions.

Variability in Length at Age

Parameters (Table 2.16) governing the amount of variability surrounding the length-at-age relationship (Appendix) were estimated directly from the observed standard deviations in the available length-at-age data (see "Data" above), giving the following values (in cm): $X_1 = 3.5$, $X_2 = 7.7$. Estimation of these two parameters constituted the only use of age data in the present assessment.

Maturity at Length

Maximum likelihood estimates of the parameters (Table 2.16) governing the female maturity-at-length schedule (Appendix) were obtained using the method described by Prentice (1976), giving the following values: $P_1 = 0.142$, $P_2 = 67.1$ cm. The variance-covariance matrix of the parameter estimates gave a standard deviation of 0.006 for the estimate of P_1, a standard deviation of 0.39 cm for the estimate of P_2, and a correlation of -0.154 between the estimates of the two parameters.

Parameters of the Joint Prior Distribution of Natural Mortality and Survey Catchability

In addition to the Synthesis parameters discussed above, the Bayesian meta-analysis made use of certain non-Synthesis parameters that were estimated independently, namely the parameters of the joint prior distribution of Q and M, which consisted of a mean for the marginal distribution of each of the two variables (μ_{Q1} and μ_{M1}), a standard deviation for the marginal distribution of each of the two variables (s_{Q1} and s_{M1}), and a correlation coefficient ($?_1$). The values of these parameters, which have remained constant since their first use in the 1996 assessment, are intended to represent the SSC's collective prior belief regarding the relative plausibility of alternative pairings of Q and M values. Values of 1.0 and 0.37 were chosen for μ_{Q1} and μ_{M1}, respectively, corresponding to the point estimates of Q and M used in Model 1. Values of 0.3 and 0.111 were chosen for s_{Q1} and s_{M1}, respectively. These were chosen so as to imply 30% coefficients of variation for both Q and M. The value of $?_1$ was set at -0.5, representing a compromise between no correlation and a perfect inverse correlation.

Parameters Estimated Conditionally

Those Synthesis parameters that are estimated internally are listed in the second part of Table 2.18. The estimates of these parameters are conditional on each other, as well as on those listed in the first part of the table and discussed in the preceding section (i.e., those Synthesis parameters that are estimated independently).

Likelihood Components

As noted in the "Model Structure" section, Synthesis is a likelihood-based framework for parameter estimation which allows several data components to be considered simultaneously. In this assessment, four fishery size composition likelihood components were included: the period 1 ("early") trawl fishery, the periods 2-3 ("late") trawl fishery, the longline fishery, and the pot fishery. In addition to the fishery size composition components, likelihood components for the size composition and biomass trend from the bottom trawl survey were included in the model. To account for possible differences in selectivity between the mostly foreign (also joint venture) and mostly domestic fisheries, the fishery size composition time series were split into pre-1989 and post-1988 eras. Also, to account for the effects of a change in the trawl survey gear, the survey size composition and biomass time series were split into pre-1982 and post-1981 eras.

The Synthesis program allows the modeler to specify "emphasis" factors that determine which components receive the greatest attention during the parameter estimation process. As in the previous two assessments, all components were given an emphasis of 1.0 in the present assessment.

Use of Size Composition Data in Parameter Estimation

Size composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear/fishery, and time period within the year. In the parameter estimation process, Synthesis weights a given size composition observation (i.e., the size frequency distribution observed in a given year, gear/fishery, and period) according to the emphasis associated with the respective likelihood component and the sample size specified for the multinomial distribution from which the data are assumed to be drawn. In developing the model upon which Synthesis was originally based, Fournier and Archibald (1982) suggested truncating the multinomial sample size at a value of 400 in order to compensate for contingencies which cause the sampling process to depart from the process that gives rise to the multinomial distribution. As in the previous two assessments, the present assessment uses a multinomial sample size equal to the square root of the true sample size, rather than the true sample size itself. Given the true sample sizes observed in the present assessment, this procedure tends to give values somewhat below 400 while still providing the Synthesis program with usable information regarding the appropriate effort to devote to fitting individual samples. Multinomial sample sizes derived by this procedure for the commercial fishery size compositions are shown in Table 2.19. In the case of survey size composition data, the square root assumption was also used, except that it was necessary to assume a true sample size for the years 1979-1985 and 1988-1989, years for which such measures are unavailable (see "Trawl Survey Data" above). For those years, a total sample size of 10,000 fish was assumed (giving a multinomial sample size of 100), which approximates the average total sample size from the other years. For the years 1986-1987 and 1990-1998, the square roots (SR) of the true survey sample sizes are shown below:

Year:	1986	1987	1990	1991	1992	1993	1994	1995	1996	1997	1998
SR(sample size):	124	103	75	85	98	102	118	96	97	96	98

Use of Survey Biomass Data in Parameter Estimation

Each year's survey biomass datum is assumed to be drawn from a lognormal distribution specific to that year. The model's estimate of survey biomass in a given year serves as the geometric mean for that year's lognormal distribution, and the ratio of the survey biomass datum's standard error to the survey biomass datum itself serves as the distribution's coefficient of variation.

MODEL EVALUATION

As discussed under "Model Structure" above, three models are focused upon in this assessment: Model 1 sets *M* and *Q* equal to the best point estimates that can be obtained independently of the Synthesis models used in the present assessment, estimates which are also used to define the means of the marginal prior distributions for these two parameters; Model 2 sets *M* and *Q* equal to their maximum likelihood estimates; and Model 3 sets *M* and *Q* equal to the means of their marginal posterior distributions.

Evaluation Criteria

Three criteria will be used to evaluate the three models developed in the present assessment: 1) the effective sample sizes of the size composition data, 2) the root mean squared error (RMSE) of the fit to the survey biomass data, and 3) the overall reasonableness of the parameter estimates.

Effective Sample Size

Once maximum likelihood estimates of the model parameters have been obtained, Synthesis computes an "effective" sample size for the size composition data specific to a particular year, gear/fishery, and time period within the year. The effective sample size can be interpreted as the multinomial sample size that would typically be required in order to produce the given fit. A rule of thumb for viewing a fit as "good" might be based on the relationship between effective sample size and the input sample size (i.e., if effective sample size exceeds the input sample size, the fit is reasonably good). The following table shows the average of the input sample sizes and the average effective sample sizes for each of the size composition components (in each column, the average is computed with respect to all years and periods present in the respective time series):

Likelihood Component	Average of Square Root of True Sample Size	Average Effective Sample Size Model 1	Model 2	Model 3
Early-season trawl fishery size composition	197	214	332	335
Late-season trawl fishery size composition	49	74	68	67
Longline fishery size composition	182	259	273	255
Pot fishery size composition	131	205	303	319
Pre-1982 survey size composition	100	98	109	106
Post-1981 survey size composition	100	101	120	118

Note: True sample sizes for the survey are available only for the years 1986-1987 and 1990-1998. For all other years, the average value (100) from the available years was assumed.

All three models have average effective samples at least as great as the average input values (the average values of the square roots of the true sample sizes) for all likelihood components, with the exception of the pre-1982 survey size composition component in Model 1, where the average effective sample size (98) is slightly less than the average value used in the model (100). However, it should be remembered that the values used to represent multinomial sample size for this component in the model are assumed rather than calculated, because the true sample sizes from those surveys are unknown. Model 2 has the largest average effective sample sizes for three out of the six components, while Model 3 has the largest average effective sample sizes for two (the early-season trawl fishery and the pot fishery), and Model 1 has the largest effective sample size for one (the late-season trawl fishery).

Fit to Survey Biomass Data

The log-scale RMSEs from the three models' fits to the survey biomass time series (1979 through 1998) are shown below:

Model	RMSE
1	0.192
2	0.177
3	0.191

Model 2 has the lowest survey biomass RMSE, while the RMSEs from Models 1 and 2 are virtually identical.

Overall Reasonableness of Parameter Estimates

The following table gives the model-specific estimates of length-at-age parameters K and L_2 (L_1 was estimated independently, and thus did not vary with choice of model):

Parameter	Model 1	Model 2	Model 3
K	0.204	0.246	0.238
L_2	92.8	85.6	86.4

The estimates of these two parameters do not vary drastically between models, although it may be noted that the estimates of L_2 from Models 2 and 3 are lower than the mean length of age group 12 observed in the available length-at-age data (89 cm).

Model-specific estimates of fishing mortality rates $F_{g,y,i}$, recruitments R_y and initial numbers at age N_a, and selectivity parameters $S_{1\text{-}7,g,e(y*g)}$ are shown in Tables 2.20, 2.21, and 2.22, respectively. In general, Model 1 tends to result in lower estimated fishing mortality rates than Model 2 and higher estimated fishing mortality rates than Model 3. Model 1 tends to produce the highest estimates of recruitment and initial numbers at age, and Model 2 the lowest. Model 1 tends to produce the least sharply domed selectivity curves, and Model 3 the most.

The parameter values associated with the prior distribution, smoothed and rescaled likelihood profile, and posterior distribution in the three alternative models are shown below:

Parameter	Model 1		Model 2		Model 3	
	Label	Value	Label	Value	Label	Value
marginal mean of *M*	μ_{M1}	0.37	μ_{M2}	0.045	μ_{M3}	0.128
marginal mean of *Q*	μ_{Q1}	1.00	μ_{Q2}	4.55	μ_{Q3}	1.72
marginal standard deviation of *M*	s_{M1}	0.111	s_{M2}	0.021	s_{M3}	0.011
marginal standard deviation of *Q*	s_{Q1}	0.3	s_{Q2}	0.68	s_{Q3}	0.128
correlation between *M* and *Q*	$?_1$	-0.5	$?_2$	-0.916	$?_3$	-0.661

The distributions corresponding to the above parameter values are shown in Figure 2.5.

If μ_{M1} and μ_{Q1} (Model 1) are interpreted as the expected values of *M* and *Q* prior to performing the assessment, the parameter estimates that describe the smoothed likelihood profile are remarkable. Not only are the maximum likelihood estimates of *M* and *Q* (Model 2) vastly different from μ_{M1} and μ_{Q1}, the 95% confidence intervals of the two distributions do not even come close to overlapping. The means of the marginal posterior distributions (Model 3) are intermediate between the corresponding estimates associated with Models 1 and 2, but again the estimates of the marginal standard deviations are so small (particularly s_{M3}) that the 95% confidence intervals of the prior and posterior distributions overlap only in one small region of (*M*,*Q*)-space far removed from μ_{M1} and μ_{Q1}. In no case do the estimates of the marginal means from one model fall within the 95% confidence interval for either of the other two models.

Selection of Final Model

One of the main purposes of stock assessments such as the present one is to provide reference estimates of historic biomass trends, target and limit harvest rates, and biomass projections. It is therefore convenient to choose a single model which can be used to generate a set of such reference estimates. As shown by the effective sample sizes associated with the size composition data and the RMSE of the survey biomass estimates, Model 2 (where *M* and *Q* are set equal to their respective maximum likelihood estimates) gives the best fit to the data, as would be expected from the fact that Model 2 is designed to do exactly that. Model 3 (where *M* and *Q* are set equal to the means of the respective marginal posterior distributions) gives the next best fit to the data, followed by Model 1 (where *M* and *Q* are set equal to the means of the respective marginal prior distributions). However, the differences between the estimates of *M* and *Q* in Models 2 and 3 (particularly Model 2) with respect to the estimates of *M* and *Q* in Model 1 are so striking as to call into question the significance of the improved fits obtained by Models 2 and 3. It may be noted that Model 1 has served as the baseline model for reporting reference estimates in each of the two most recent assessments. Even though Models 2 and 3 give superior fits to that given by Model 1, it is not clear that this constitutes sufficient grounds for abandoning the use of Model 1 as a tool for generating reference estimates. In fact, given the extreme values of M and Q associated with Models 2 and 3, it seems best to retain the use of Model 1 as a tool for generating reference estimates, for the time being at least. Nevertheless, selection of Model 1 for this specific purpose does not have to imply that other models or parameter combinations cannot be considered for other uses, such as recommending an acceptable biological catch for 1999.

Parameter Estimates Associated with the Final Model

The parameter estimates associated with Model 1 are shown in the columns labeled "Model 1" in the preceding section and in Tables 2.20, 2.21, and 2.22. In addition, the parameter estimates listed in the section entitled "Parameters Estimated Independently" also pertain to Model 1.

Schedules Defined by Final Parameter Estimates

Lengths at age defined by the final parameter estimates are shown below (lengths are in cm and are evaluated at the mid-point of each age group):

Age group:	1	2	3	4	5	6	7	8	9	10	11	12
Average length:	18	34	47	57	65	72	78	82	86	89	92	94

The distribution of lengths at age (measured in mid-year) defined by the final parameter estimates is shown in Table 2.23.

Weights at length and maturity proportions at length defined by the final parameters are shown in Table 2.24, and selectivities at length defined by the final parameter estimates are shown in Table 2.25.

RESULTS

Definitions

The biomass estimates presented here will be defined in three ways: 1) age 3+ biomass, consisting of the biomass of all fish aged three years or greater in January of a given year (vector *b* in Appendix); 2) spawning biomass, consisting of the biomass of all spawning females in March of a given year (vector *c* in Appendix); and 3) survey biomass, consisting of the biomass of all fish that the Model estimates should have been observed by the survey in July of a given year (vector *d* in Appendix). The recruitment estimates presented here will be defined as numbers of age 3 fish in January of a given year (note that this is different from the recruitment parameter R_y, which represents numbers at age 1 in January of year *y*). The fishing mortality rates presented here will be defined as full-selection, instantaneous fishing mortality rates expressed on a per annum scale.

Biomass

Model 1’s description of the recent history of the stock (EBS portion only) is shown in Table 2.26, together with estimates provided in last year’s final SAFE report (Thompson and Dorn 1997). The biomass trends estimated in the present assessment are also shown in Figure 2.6. The model’s estimated time series of “survey” biomass parallels the biomass trend from the actual survey fairly closely. Both trends show an increase during the early 1980s followed by a period of sustained high abundance throughout most of that decade, a decline through 1991, an increase through 1994, and continued decline to the present. The biomass observed by the actual 1998 survey was very nearly the lowest on record (exceeding the lowest observed value by less than 0.3%), while the model’s estimate of survey biomass for 1998 was the lowest in the time series. The model’s estimate of survey biomass for 1998 is within 0.5% of the value observed by the actual survey.

Paralleling the estimated survey biomass trend, the model’s estimated age 3+ biomass and spawning biomass levels show declines since 1995. The model’s estimate of 1998 age 3+ biomass is the lowest in the time series since 1980, and the model’s estimate of 1998 spawning biomass is the lowest in the time series since 1981.

Recruitment

Model 1’s estimated time series of age 3 recruitments is shown in Table 2.27, together with the estimates provided in last year’s final SAFE report (Thompson and Dorn 1997). The current time series has a mean value of 212 million fish and shows a high degree of variability, with an estimated coefficient of variation (assuming a lognormal distribution) of 65%.

One possible means of assigning a qualitative ranking to each year class within this time series is as follows: an “above average” year class can be defined as one in which numbers at age 3 are at least 120% of the mean, an “average” year class can be defined as one in which numbers at age 3 are less than 120% of the mean but at least 80% of the mean, and a “below average” year class can be defined as one in which numbers at age 3 are less than 80% of the mean. These criteria give the following classification of year class strengths:

Above average:	1977	1978	1979	1982	1984	1992					
Average:	1980	1985	1989	1990							
Below average:	1975	1976	1981	1983	1986	1987	1988	1991	1993	1994	1995

Except for the addition of the below-average 1995 year class, these results are identical to those presented in last year's SAFE report (Thompson and Dorn 1997). With the addition of the 1995 year class, it may be noted that the three most recent year classes observed at age 3 have all been below average. The 1996 year class is currently expected to break this pattern when it recruits at age 3 next year, however. The model's present estimate of the 1996 cohort's abundance at age 1 (based mostly on the 1997 and 1998 bottom trawl surveys) is about average. Nevertheless, even if the 1996 year class were to recruit at the level currently anticipated, the departure from the recent trend of weak year classes may be short lived, as the present prognosis for the 1997 year class is very poor. The model's estimate of recruitment at age 1 from the 1997 year class (based almost entirely on its strength in this year's bottom trawl survey) is the smallest estimated age 1 recruitment in the entire time series (approximately 38% smaller than the next-smallest value).

Exploitation

Model 1's estimated time series of the ratio between EBS catch and age 3+ biomass is shown in Table 2.28, together with the estimates provided in last year's final SAFE report (Thompson and Dorn 1997). The average value of this ratio over the entire time series is about 0.09. The estimated values exceed the average for every year after 1989, whereas the estimated values fall below the average for every year prior to 1990 except 1978.

PROJECTIONS AND HARVEST ALTERNATIVES

Allocation of Fishing Mortality Between Gear Types

In June of 1996, the Council approved an agreement negotiated by affected industry groups to update the allocation formula described in Amendment 24 to the Fishery Management Plan for the Groundfish Fishery of the Bering Sea and Aleutian Islands Area (BSAI Groundfish FMP). The new allocation formula specifies that future catches of Pacific cod will be allocated according to gear type as follows: the trawl fishery will be allocated 47%, the fixed gear (longline and pot) fishery will be allocated 51%, and the jig fishery will be allocated 2%. This allocation formula was integrated into model projections as follows: First, since available data are insufficient to estimate selectivities for the jig fishery, the jig fishery was merged into the other commercial fisheries. Second, total fishing mortality was apportioned between gear types (early trawl, late trawl, longline, and pot) at a ratio of 376:55:464:105. These proportions result in a mix of fishing mortality that matches both the 47:51 trawl:fixed allocation and the recent (1995-1997) average distribution of catches between the early and late trawl fisheries and between the longline and pot fisheries.

Reference Points Defined in Terms of Spawning Per Recruit

Reliable estimates of maximum sustainable yield (MSY), the equilibrium fishing mortality rate at

MSY, and the equilibrium spawning biomass level at MSY are currently not available for the Pacific cod stock in the EBS or AI. However, it is possible to estimate various reference points relating to equilibrium levels of spawning per recruit (SPR). The fishing mortality rate corresponding to three traditional SPR reference points are shown below, where the notation "$F_{SPR\%}$" denotes the fishing mortality rate that reduces the level of equilibrium SPR to a specified percentage of the pristine (i.e., equilibrium unfished) level:

Strategy:	$F_{40\%}$	$F_{35\%}$	$F_{30\%}$
F value:	0.29	0.34	0.41

Assuming an equilibrium recruitment equal to the historic average level (i.e., the arithmetic mean of all estimated recruitments in the time series), it is possible to estimate equilibrium stock sizes under various fishing mortality rates. For example, in the case of a zero fishing mortality rate, the equilibrium age 3+ biomass is estimated at a value of 2,300,000 t for the EBS portion of the stock, or 2,690,000 t for the EBS and AI combined. In terms of spawning biomass, the estimates are 735,000 t and 858,000 t, respectively. Another potentially useful reference point is the equilibrium stock biomass that would result from fishing at the $F_{40\%}$ rate under the assumption that recruitment is constant at the historic average level. For the EBS portion of the stock, this stock size is 1,250,000 t measured as age 3+ biomass and 294,000 t measured as spawning biomass. For the EBS and AI combined, the respective estimates are 1,460,000 t (age 3+ biomass) and 343,000 t (spawning biomass). The equilibrium spawning stock size obtained under an $F_{40\%}$ harvest rate is denoted $B_{40\%}$.

Amendment 44 Requirements

Amendment 44 to the BSAI Groundfish FMP defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC (F_{ABC}). Because reliable estimates of MSY-related reference points are currently not available but reliable estimates of SPR-related reference points are available, Pacific cod in the BSAI are managed under Tier 3 of Amendment 44. The following formulae apply under Tier 3:

3a) *Stock status:* $B/B_{40\%} > 1$
$F_{OFL} = F_{30\%}$
$F_{ABC} \# F_{40\%}$
3b) *Stock status:* $1/20 < B/B_{40\%} \# 1$
$F_{OFL} = F_{30\%} \times (B/B_{40\%} - 1/20) \times 20/19$
$F_{ABC} \# F_{40\%} \times (B/B_{40\%} - 1/20) \times 20/19$
3c) *Stock status:* $B/B_{40\%} \# 1/20$
$F_{OFL} = 0$
$F_{ABC} = 0$

The ratio of next year's spawning biomass to $B_{40\%}$ is the key to determining the sub-tier under which a stock is to be managed. In the case of Pacific cod, spawning biomass is measured in March, the month of peak spawning. Therefore, the estimate of next year's spawning biomass level is conditional on next year's fishing mortality rate. For example, if the Pacific cod stock were exploited next year at a fishing mortality rate equal to $F_{40\%}$, the estimate of next year's spawning biomass would be 281,000 t for the EBS, below the corresponding $B_{40\%}$ value of 294,000 t. The ratio of these two values (0.96) is sufficient to determine that BSAI Pacific cod should be managed under Tier 3b, but it does not necessarily imply that this ratio is the correct one to use in the formulae defining next year's F_{OFL} and maximum permissible F_{ABC} values. This is because Amendment 44 does not specify which future fishing mortality rate is to be used for projecting next year's spawning biomass in the case of stocks (such as Pacific cod) which have a peak spawning month other than January. For purposes of calculating F_{OFL} and maximum permissible F_{ABC} values under Amendment 44, this assessment will estimate next year's spawning biomass under the assumption that next year's fishing mortality rate equals the rate being calculated. For example, if F_{OFL} is the rate being calculated, next year's spawning biomass will be estimated under the assumption that next year's fishing mortality rate equals F_{OFL}, which means that the equation defining F_{OFL} describes an implicit (rather than an explicit) solution. Thus, the value of F_{OFL} is the fishing mortality rate that solves the implicit equation:

$$F = F_{30\%} \times (B(F)/B_{40\%} - 1/20) \times 20/19.$$

This value is approximately 0.39, corresponding to a relative equilibrium SPR value of 31.7%, a projected 1999 spawning biomass of 277,000 t for the EBS or 324,000 t for the BSAI, and a projected 1999 catch of 227,000 t for the EBS or 264,000 t for the BSAI.

Likewise, the maximum permissible value of F_{ABC} is the fishing mortality rate that solves the implicit equation:

$$F = F_{40\%} \times (B(F)/B_{40\%} - 1/20) \times 20/19.$$

This value is approximately 0.28, corresponding to a relative equilibrium SPR value of 41.3%, a projected 1999 spawning biomass of 282,000 t for the EBS or 329,000 t for the BSAI, and a projected 1999 catch of 168,000 t for the EBS or 196,000 t for the BSAI.

Alternative Harvest Strategies

As discussed in the preceding section, harvest strategies of particular interest under Amendment 44 include $F_{30\%}$, $F_{31.7\%}$, $F_{40\%}$, and $F_{41.3\%}$. However, in terms of F_{ABC}, Amendment 44 establishes only a maximum permissible value, leaving open the question of what, if any, lower value(s) might also be of particular interest. For the past two years, the BSAI and GOA Pacific cod assessments have examined a harvest strategy that formally addresses uncertainty in two key parameters, *M* and *Q*. This strategy relies on the Bayesian meta-analysis described under the heading "Model Structure" above. Given the posterior distribution for *M* and *Q* derived in the meta-analysis, the next step was to profile the 1999 ABC obtained under an $F_{40\%}$ harvest strategy as a function of *M* and *Q*. The log-ABC profile was smoothed by fitting it to the following bivariate quadratic function:

$$\ln(ABC) = \beta_0 + \beta_{M1} M + \beta_{Q1} Q + \beta_{M2} M^2 + \beta_{Q2} Q^2 + \beta_{MQ} MQ\ .$$

The parameter estimates were as shown below, giving the relationship shown in the upper panel of Figure 2.7 (where the ranges of values along the *M* and *Q* axes represent plus or minus two standard deviations from the means of the respective marginal posterior distributions):

Parameter:	$ß_0$	$ß_{M1}$	$ß_{Q1}$	$ß_{M2}$	$ß_{Q2}$	$ß_{MQ}$
Value:	15.87	-15.42	-2.202	17.15	0.2057	4.196

Next, multiplying the posterior distribution by the above equation gives the weighted log-ABC profile shown in the lower panel of Figure 2.7. Taking the antilogarithm of the area under the curve gives the geometric mean ABC for 1999, which has a value of 152,000 t for the EBS or 177,000 t for the BSAI. The geometric mean was considered to be the risk-averse optimum in the previous two assessments. Under Model 1, a 1999 catch of 152,000 t corresponds to a fishing mortality rate of about 0.25, which translates into a relative equilibrium SPR level of 44.4%.

Recruitment Scenarios and Five-Year Projections

The projected 1999 catches described above are essentially independent of the level of age 1 recruitment assumed for 1999 because age 1 fish have almost negligible weight and the selectivities of this age group are approximating zero for all commercial gear types. However, catch projections beyond 1999 do depend on the level of age 1 recruitment assumed. To understand the sensitivity of catch projections to the recruitment assumption, four recruitment scenarios are examined in this assessment. Each scenario holds recruitment constant at some mean level. The scenarios differ only in terms of the type of mean (arithmetic or geometric) and the range of years (most recent 10 years or the entire 21-year time series) used in the computation. These are described in the table below:

Scenario:	1	2	3	4
Mean:	Arithmetic	Arithmetic	Geometric	Geometric
Horizon:	Short-term (10-year)	Long-term (21-year)	Short-term (10-year)	Long-term (21-year)
Recruits:	340,000,000	447,000,000	302,000,000	371,000,000

Given the five alternative harvest strategies listed in the preceding section and the four alternative recruitment scenarios listed in the table above, five-year projections of age 3+ biomass, spawning biomass, and catch were made. These are shown in Tables 2.29, 2.30, 2.31, and 2.32 for recruitment scenarios 1, 2, 3, and 4, respectively. Overall, these projections indicate that further declines in the BSAI Pacific cod stock can be expected, even under a conservative exploitation strategy. However, it should be stressed that these projections are all based on constant recruitment assumptions, and could prove in retrospect to be either overly pessimistic or overly optimistic depending on the level of future recruitment that actually occurs.

ABC Recommendation

For 1998, the Council set the BSAI ABC at 210,000 t, which corresponded to the geometric mean catch projected in last year's assessment under an $F_{40\%}$ harvest strategy. The same strategy is recommended for use in setting the 1999 ABC. For 1999, the geometric mean catch under an $F_{40\%}$ harvest strategy is 152,000 t for the EBS and 177,000 t for the BSAI. Under Model 1, this corresponds to a fishing mortality rate of 0.25. A 1999 catch of 177,000 t for BSAI Pacific cod would be approximately 9% below the maximum permissible level under Amendment 44 (196,000 t), a reduction which is warranted on the basis of the Bayesian meta-analysis described under the heading "Alternative Harvest Strategies" above.

Other methods for computing a prudent, uncertainty-motivated reduction from the maximum permissible ABC level could also be considered. For example, the 1996 ABC for GOA Pacific cod was determined by choosing the minimum $F_{40\%}$ catch located on the boundary of the 95% confidence interval for M, where the likelihood function was used as the basis for defining the confidence interval. From the information described under the heading "Model Evaluation" above, it can be shown that the minimum $F_{40\%}$ catch located on the boundary of the 95% confidence ellipse for the parameters M and Q is as follows, depending on which distribution is used as the basis for defining the confidence ellipse (values pertain to the BSAI): 1) 121,000 t, using the prior distribution; 2) 21,600 t, using the likelihood function; and 3) 93,000 t, using the posterior distribution.

Another possible method of adjusting the maximum permissible ABC to account for uncertainty was suggested by the SSC at its October, 1998 meeting. The SSC suggested averaging the point estimates of the maximum permissible ABC under Models 1 and 2, with the point estimates from those two models providing a range. As already noted, the point estimate of the maximum permissible ABC for 1999 under Model 1 is 196,000 t for the BSAI. Under Model 2, the point estimate of the $F_{40\%}$ catch for 1999 is 35,200 t. However, under Model 2, the ratio of projected spawning biomass to $B_{40\%}$ is extremely low, and the maximum permissible ABC for 1999 is only 4,700 t. Thus, the 1999 ABC computed under the SSC's formula would be approximately 100,000 t, with a range of 4,700-196,000 t.

OTHER CONSIDERATIONS

The prey and predators of Pacific cod have been described or reviewed by Albers and Anderson (1985), Livingston (1989, 1991), and Westrheim (1996). In terms of percent occurrence, the most important items in the diet of Pacific cod in the BSAI and GOA are polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, the most important dietary items are euphausids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, the most important dietary items are walleye pollock, fishery offal, and yellowfin sole. Small Pacific cod feed mostly on invertebrates, while large Pacific cod are mainly piscivorous. Predators of Pacific cod include halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffin.

The above qualitative description of Pacific cod's trophic relationships notwithstanding, to date it has not been possible to incorporate ecosystem interactions into the model used to assess the Pacific cod stock. No recommendations regarding adjustment of the Pacific cod ABC on the basis of ecosystem considerations are made at this time.

SUMMARY

The major results of the Pacific cod stock assessment are summarized in Table 2.33.

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Table 2.1--Summary of catches (t) of Pacific cod by management area, fleet sector, and gear type (page 1 of 3). All catches since 1980 include discards. Yr. = year, LLine = longline, Subt. = sector subtotal. Catches for 1998 are through August. Catches by gear are not available prior to 1981.

Eastern Bering Sea Only:

Yr.	Foreign			Joint Venture		Domestic Annual Processing					Total
	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	
78			42512		0					31	42543
79			32981		0					780	33761
80			35058		8370					2433	45861
81	30347	5851	36198	7410	7410	12884	1	0	14	12899	56507
82	23037	3142	26179	9312	9312	23893	5	0	1715	25613	61104
83	32790	6445	39235	9662	9662	45310	4	21	569	45904	94801
84	30592	26642	57234	24382	24382	43274	8	0	205	43487	125103
85	19596	36742	56338	35634	35634	51425	50	0	0	51475	143447
86	13292	26563	39855	57827	57827	37646	48	62	167	37923	135605
87	7718	47028	54746	47722	47722	46039	1395	1	0	47435	149903
88	0	0	0	106592	106592	93706	2474	299	0	96479	203071
89	0	0	0	44612	44612	119631	13935	145	0	133711	178323
90	0	0	0	8078	8078	115493	47114	1382	0	163989	172067
91	0	0	0	0	0	128401	76625	3343	0	208369	208369
92	0	0	0	0	0	75888	79106	7381	33	162408	162408
93	0	0	0	0	0	81762	49293	2098	2	133155	133155
94	0	0	0	0	0	85637	79757	8107	730	174231	174231
95	0	0	0	0	0	110773	97964	19230	599	228567	228567
96	0	0	0	0	0	91910	88882	28006	267	209064	209064
97	0	0	0	0	0	93924	117008	21493	173	232598	232598
98	0	0	0	0	0	50529	54126	11733	176	116564	116564

Table 2.1--Summary of catches (t) of Pacific cod by management area, fleet sector, and gear type (page 2 of 3). All catches since 1980 include discards. Yr. = year, LLine = longline, Subt. = sector subtotal. Catches for 1998 are through August. Catches by gear are not available prior to 1981.

Aleutian Islands Region Only:

Yr.	Foreign			Joint Venture		Domestic Annual Processing					Total
	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	
78			0		0					0	0
79			0		0					0	0
80			0		86					0	86
81	2680	235	2915	1749	1749	2744	26	0	0	2770	7434
82	1520	476	1996	4280	4280	2121	0	0	0	2121	8397
83	1869	402	2271	4700	4700	1459	0	0	0	1459	8430
84	473	804	1277	6390	6390	314	0	0	0	314	7981
85	10	829	839	5638	5638	460	0	0	0	460	6937
86	5	0	5	6115	6115	784	1	1	0	786	6906
87	0	0	0	10435	10435	2662	22	88	0	2772	13207
88	0	0	0	3300	3300	1698	137	30	0	1865	5165
89	0	0	0	6	6	4233	284	19	0	4536	4542
90	0	0	0	0	0	6932	602	7	0	7541	7541
91	0	0	0	0	0	3283	3071	3330	0	9684	9684
92	0	0	0	0	0	14376	22143	6300	84	42903	42903
93	0	0	0	0	0	17312	16860	0	33	34205	34205
94	0	0	0	0	0	14905	7381	147	0	22433	22433
95	0	0	0	0	0	10576	4974	1017	0	16567	16567
96	0	0	0	0	0	21179	5819	4611	0	31609	31609
97	0	0	0	0	0	17349	7151	575	89	25164	25164
98	0	0	0	0	0	18741	10279	321	0	29340	29340

Table 2.1--Summary of catches (t) of Pacific cod by management area, fleet sector, and gear type (page 3 of 3). All catches since 1980 include discards. Yr. = year, LLine = longline, Subt. = sector subtotal. Catches for 1998 are through August. Catches by gear are not available prior to 1981.

Eastern Bering Sea and Aleutian Islands Region Combined:

Yr.	Foreign			Joint Venture		Domestic Annual Processing					Total
	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	
78			42512		0					31	42543
79			32981		0					780	33761
80			35058		8456					2433	45947
81	33027	6086	39113	9159	9159	15628	27	0	14	15669	63941
82	24557	3618	28175	13592	13592	26014	5	0	1715	27734	69501
83	34659	6847	41506	14362	14362	46769	4	21	569	47363	103231
84	31065	27446	58511	30772	30772	43588	8	0	205	43801	133084
85	19606	37571	57177	41272	41272	51885	50	0	0	51935	150384
86	13297	26563	39860	63942	63942	38430	49	63	167	38709	142511
87	7718	47028	54746	58157	58157	48701	1417	89	0	50207	163110
88	0	0	0	109892	109892	95404	2611	329	0	98344	208236
89	0	0	0	44618	44618	123864	14219	164	0	138247	182865
90	0	0	0	8078	8078	122425	47716	1389	0	171530	179608
91	0	0	0	0	0	131684	79696	6673	0	218053	218053
92	0	0	0	0	0	90264	101249	13681	117	205311	205311
93	0	0	0	0	0	99074	66153	2098	35	167360	167360
94	0	0	0	0	0	100542	87138	8254	730	196664	196664
95	0	0	0	0	0	121349	102939	20248	599	245135	245135
96	0	0	0	0	0	113089	94701	32617	267	240673	240673
97	0	0	0	0	0	111273	124159	22068	262	257762	257762
98	0	0	0	0	0	69270	64405	12053	176	145905	145905

Table 2.2--History of Pacific cod ABC, TAC, total BSAI catch, and type of stock assessment model used to recommend ABC. Catch for 1998 is current through August 30.

Year	ABC	TAC	Catch	Stock Assessment Model
1980	148,000	70,700	45,947	projection of 1979 survey numbers at age
1981	160,000	78,700	63,941	projection of 1979 survey numbers at age
1982	168,000	78,700	69,501	projection of 1979 survey numbers at age
1983	298,200	120,000	103,231	projection of 1979 survey numbers at age
1984	291,300	210,000	133,084	projection of 1979 survey numbers at age
1985	347,400	220,000	150,384	projection of 1979-1985 survey numbers at age
1986	249,300	229,000	142,511	separable age-structured model
1987	400,000	280,000	163,110	separable age-structured model
1988	385,300	200,000	208,236	separable age-structured model
1989	370,600	230,681	182,865	separable age-structured model
1990	417,000	227,000	179,608	separable age-structured model
1991	229,000	229,000	218,053	separable age-structured model
1992	182,000	182,000	205,311	age-structured Synthesis model
1993	164,500	164,500	167,360	length-structured Synthesis model
1994	191,000	191,000	196,664	length-structured Synthesis model
1995	328,000	250,000	245,135	length-structured Synthesis model
1996	305,000	270,000	240,673	length-structured Synthesis model
1997	306,000	270,000	257,762	length-structured Synthesis model
1998	210,000	210,000	145,905	length-structured Synthesis model

Table 2.3--Species ("Spe") discards in the 1996 Pacific cod fisheries, expressed as percentages of the total catch of all species in those fisheries. All species whose discards comprised at least one percent of the total catch in a given fishery are shown. For example, the entries "MG" and "6.5" near the top of the list under "Eastern Bering Sea" and "Longline" mean that discards of "miscellaneous groundfish" comprised 6.5% of the total catch of all species in the EBS longline fishery for Pacific cod in 1996.

Eastern Bering Sea						Aleutian Islands Region						Gulf of Alaska					
Longline		Pot		Trawl		Longline		Pot		Trawl		Longline		Pot		Trawl	
Spe	%	Spe	%	Spe	%	Spe	%	Spe	%	Spe	%	Spe	%	Spe	%	Spe	%
MG	6.5	MG	1.6	WP	18.9	PC	6.6	PC	1.9	AM	3.8	MG	3.4	MG	1.0	AF	2.8
PC	2.8	PC	1.4	RS	8.0	MG	5.8	MG	1.8	PC	2.6	PC	1.9			WP	2.3
WP	2.5			MG	3.3					RS	1.3					PC	1.8
AF	1.8			AF	3.2					SN	1.1						
				PC	2.9												
				FS	2.5												
				YS	1.3												

Key:
- AF = arrowtooth flounder
- AM = Atka mackerel
- FS = flathead sole
- MG = miscellaneous groundfish
- PC = Pacific cod
- RS = rock sole
- SN = sharpchin/northern rockfish
- WP = walleye pollock
- YS = yellowfin sole

Table 2.4--Discards of Pacific cod in the 1996 fisheries, expressed as percentages of the total area-wide Pacific cod catch. All fisheries in which Pacific cod discards comprised at least one percent of the total area-wide Pacific cod catch are shown. For example, the entries "WP," "TWL-M," and "2.8" near the top of the list under "Eastern Bering Sea" mean that Pacific cod discards in the midwater trawl fishery for walleye pollock comprised 2.8% of the total Pacific cod catch from all EBS fisheries in 1996.

Eastern Bering Sea			Aleutian Islands Region			Gulf of Alaska		
Target	Gear	%	Target	Gear	%	Target	Gear	%
WP	TWL-M	2.8	AM	TWL	6.8	SF	TWL	4.4
YS	TWL	2.1	PC	LGL	1.3	AF	TWL	1.9
WP	TWL-B	2.1	PC	TWL	1.1	FS	TWL	1.3
RS	TWL	1.6				PC	TWL	1.1
PC	TWL	1.4						
PC	LGL	1.4						

Key:

Target Fisheries	
AF	= arrowtooth flounder
AM	= Atka mackerel
FS	= flathead sole
PC	= Pacific cod
RS	= rock sole
SF	= shallow-water flatfish
WP	= walleye pollock
YS	= yellowfin sole

Gear Type	
LGL	= longline
TWL	= trawl
TWL-B	= bottom trawl
TWL-M	= midwater trawl

Table 2.5--Catch (t) of Pacific cod by year, gear, and period. Catch for 1998 is complete through period 2. Distribution of catch for 1978-1980 by gear and period was estimated from other years' data.

Year	Trawl			Longline			Pot		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
1978	10424	11288	18021	1371	1032	1856	0	0	0
1979	10397	12587	10403	1371	699	547	0	0	0
1980	9452	9007	17039	1106	206	4230	0	0	0
1981	15067	14087	21486	1286	624	3942	0	0	0
1982	21742	18151	16348	363	475	2308	0	0	0
1983	40757	24300	22705	2941	748	2756	0	0	0
1984	48237	24964	25045	5012	2128	19508	0	0	0
1985	55673	28673	22310	13703	1710	21379	0	0	0
1986	59786	26598	22382	8895	438	17278	0	0	0
1987	64413	15604	21462	20947	723	26752	0	0	0
1988	127470	25662	47166	444	646	1385	90	51	160
1989	127459	16986	19798	3810	4968	5157	33	63	49
1990	101645	11402	10524	13171	16643	17299	0	986	395
1991	108382	16600	3419	27719	21188	27718	13	1271	2059
1992	58524	11715	5649	48598	24295	6213	2536	4583	262
1993	67120	5362	9280	49242	27	23	2073	24	0
1994	61304	1382	4386	58639	5	4720	4961	0	500
1995	90138	8543	12092	68764	26	29174	12496	3411	3323
1996	78194	3126	10590	62011	26	26845	18143	6401	3462
1997	81313	8030	4581	70676	6546	39787	14584	4107	2802
1998	45093	5436	0	54100	26	0	9020	2713	0

Table 2.6--Pacific cod length sample sizes from the commercial fisheries.

Year	Trawl Fishery			Longline Fishery			Pot Fishery		
	Per. 1	Per. 2	Per. 3	Per. 1	Per. 2	Per. 3	Per. 1	Per. 2	Per. 3
1978	646	0	3161	2885	4886	2514	0	0	0
1979	1667	0	748	11410	2514	2662	0	0	0
1980	1359	73	327	2600	1389	2932	0	0	0
1981	132	0	1540	2253	1276	1300	0	0	0
1982	592	226	1643	2910	1203	5078	0	0	0
1983	12386	1231	14577	18800	4119	9610	0	0	0
1984	10246	4482	4477	6853	6004	82103	0	0	0
1985	30171	1556	3051	0	4561	134469	0	0	0
1986	28566	1813	2548	18588	200	104142	0	0	0
1987	46360	6674	20923	70273	0	165124	0	0	0
1988	103453	0	2897	0	0	0	0	0	0
1989	58575	612	669	0	0	0	0	0	0
1990	64143	9807	250	18900	74534	62550	0	1506	5772
1991	88727	2083	0	54671	70808	91693	0	10701	11243
1992	79286	0	0	152152	134263	20129	17289	48569	5147
1993	81637	0	0	154337	0	0	10557	0	0
1994	103839	0	0	172585	0	45350	25950	0	6436
1995	68575	0	0	144739	392	74766	47660	16786	13741
1996	104295	1139	3473	164051	156	75385	76393	23063	11199
1997	106847	275	0	184741	109	144489	43859	11760	11760
1998	94285	0	0	158814	0	0	26058	4882	0

Table 2.7–Number of Pacific cod lengths sampled in 1994, partitioned by gear (trawl, longline, pot), location (at sea or on shore), period (1=Jan-May, 2=Jun-Aug, 3=Sep-Dec), and area (see Figure 2.4).

Per.	Area	Trawl			Longline			Pot			Total
		Sea	Shore	Subtot.	Sea	Shore	Subtot.	Sea	Shore	Subtot.	
1	509	59421	30807	90228	12227	161	12388	5769	3627	9396	112012
1	513	419	162	581	8788	0	8788	0	0	0	9369
1	514	0	0	0	66	0	66	0	0	0	66
1	517	35750	13948	49698	26869	0	26869	3674	148	3822	80389
1	518	0	0	0	9377	0	9377	905	559	1464	10841
1	519	1623	652	2275	2720	144	2864	9408	2595	12003	17142
1	521	1051	0	1051	80404	0	80404	1788	580	2368	83823
1	523	0	0	0	8193	0	8193	0	0	0	8193
1	524	553	0	553	3281	0	3281	0	0	0	3834
1	541	4174	0	4174	14613	0	14613	150	0	150	18937
1	542	855	0	855	4356	0	4356	0	0	0	5211
1	543	0	0	0	1276	0	1276	0	0	0	1276
1	550	0	0	0	292	0	292	0	0	0	292
1	All	103846	45569	149415	172462	305	172767	21694	7509	29203	351385
3	509	0	0	0	4898	0	4898	1762	700	2462	7360
3	513	0	0	0	3355	0	3355	0	0	0	3355
3	517	0	0	0	10664	0	10664	54	0	54	10718
3	518	0	0	0	0	0	0	536	0	536	536
3	519	0	0	0	788	0	788	2595	789	3384	4172
3	521	0	0	0	20174	0	20174	0	0	0	20174
3	523	0	0	0	670	0	670	0	0	0	670
3	524	0	0	0	602	0	602	0	0	0	602
3	541	0	0	0	1169	0	1169	0	0	0	1169
3	542	0	0	0	2916	0	2916	0	0	0	2916
3	543	0	0	0	66	0	66	0	0	0	66
3	550	0	0	0	51	0	51	0	0	0	51
3	All	0	0	0	45353	0	45353	4947	1489	6436	51789
Total		103846	45569	149415	217815	305	218120	26641	8998	35639	403174

Table 2.8–Number of Pacific cod lengths sampled in 1995, partitioned by gear (trawl, longline, pot), location (at sea or on shore), period (1=Jan-May, 2=Jun-Aug, 3=Sep-Dec), and area (see Figure 2.4).

Per.	Area	Trawl			Longline			Pot			Total
		Sea	Shore	Subtot.	Sea	Shore	Subtot.	Sea	Shore	Subtot.	
1	509	9423	2774	12197	23851	0	23851	8858	5517	14375	50615
1	513	17	0	17	9588	0	9588	0	0	0	9605
1	514	0	0	0	75	0	75	40	0	40	115
1	516	0	0	0	276	0	276	0	0	0	276
1	517	49500	24718	74218	15501	0	15501	4511	3839	8350	99218
1	518	54	0	54	3375	0	3375	738	0	738	4167
1	519	6	274	280	709	642	1351	14614	10195	24809	26777
1	521	3431	0	3431	71380	0	71380	0	0	0	74811
1	523	0	0	0	11844	0	11844	0	0	0	11844
1	524	1460	0	1460	1074	0	1074	0	0	0	2534
1	541	3413	0	3413	5956	0	5956	2293	0	2293	11662
1	542	1286	0	1286	743	0	743	1232	0	1232	3261
1	All	68590	27766	96356	144372	642	145014	32286	19551	51837	294885
2	509	0	0	0	0	0	0	447	1149	1596	1596
2	517	0	0	0	0	0	0	4425	813	5238	5283
2	518	0	0	0	0	0	0	21	123	144	144
2	519	0	0	0	0	97	97	3277	2892	6169	6898
2	521	0	0	0	0	0	0	460	0	460	460
2	541	0	0	0	105	0	105	605	0	605	710
2	542	0	0	0	0	0	0	4204	0	4204	4204
2	All	0	0	0	105	97	202	13439	4977	18416	19295
3	501	0	0	0	0	0	0	0	38	38	38
3	509	0	0	0	1764	0	1764	253	400	653	2417
3	513	0	0	0	6506	0	6506	0	0	0	6506
3	516	0	0	0	0	0	0	225	0	225	225
3	517	667	68	735	16934	0	16934	314	231	545	18314
3	518	0	0	0	2746	0	2746	1336	62	1398	4144
3	519	0	0	0	2457	0	2457	3908	3653	7561	10649
3	521	0	0	0	29523	0	29523	0	0	0	29523
3	523	0	0	0	5699	0	5699	0	0	0	5699
3	524	0	0	0	1611	0	1611	0	0	0	1611
3	541	0	0	0	6743	0	6743	896	0	896	7639
3	542	0	0	0	164	0	164	2604	0	2604	2768
3	543	0	0	0	626	0	626	0	0	0	626
3	All	667	68	735	74773	0	74773	9536	4384	13920	90159
Total		69257	27834	97091	219250	739	219989	55261	28912	84173	404339

Table 2.9–Number of Pacific cod lengths sampled in 1996, partitioned by gear (trawl, longline, pot), location (at sea or on shore), period (1=Jan-May, 2=Jun-Aug, 3=Sep-Dec), and area (see Figure 2.4).

Per.	Area	Trawl			Longline			Pot			Total
		Sea	Shore	Subtot.	Sea	Shore	Subtot.	Sea	Shore	Subtot.	
1	507	0	145	145	0	0	0	0	0	0	145
1	509	53070	19890	72960	29215	0	29215	9289	10256	19545	121720
1	512	0	0	0	932	0	932	679	132	811	1743
1	513	3994	3009	7003	23650	0	23650	134	0	134	30787
1	516	32	0	32	759	0	759	3812	403	4215	5006
1	517	37050	13329	50379	11810	0	11810	10752	2657	13409	75598
1	518	54	0	54	5273	145	5418	2409	1735	4144	9616
1	519	387	707	1094	804	0	804	19167	11481	30648	32546
1	521	2154	0	2154	65688	0	65688	583	0	583	68425
1	523	27	0	27	7609	0	7609	0	0	0	7636
1	524	2156	0	2156	2212	0	2212	0	0	0	4368
1	541	4837	97	4934	14622	0	14622	7636	2274	9910	29466
1	542	526	102	628	374	0	374	190	0	190	1192
1	543	0	0	0	696	0	696	1076	0	1076	1772
1	550	38	0	38	274	0	274	81	0	81	393
1	All	104325	37279	141604	163918	145	164063	55808	28938	84746	390413
2	508	0	0	0	0	0	0	328	0	328	328
2	509	398	0	398	0	0	0	4014	3084	7098	7496
2	512	0	0	0	0	0	0	938	0	938	938
2	513	0	0	0	0	0	0	151	0	151	151
2	516	0	0	0	0	0	0	595	0	595	595
2	517	80	0	80	0	0	0	256	144	400	480
2	518	0	0	0	0	0	0	223	599	822	822
2	519	0	0	0	0	0	0	3478	2138	5616	5616
2	521	0	0	0	0	0	0	1211	0	1211	1211
2	541	661	0	661	157	0	157	3941	0	3941	4759
2	542	0	0	0	0	0	0	743	0	743	743
2	543	0	0	0	0	0	0	1226	0	1226	1226
2	All	1139	0	1139	157	0	157	17104	5965	23069	24365
3	509	506	301	807	18960	0	18960	1755	114	1869	21636
3	512	0	0	0	0	0	0	153	0	153	153
3	513	0	0	0	9140	0	9140	0	0	0	9140
3	516	0	0	0	210	0	210	279	0	279	489
3	517	2425	1362	3787	14138	0	14138	201	258	459	18384
3	518	0	0	0	312	0	312	1187	0	1187	1499
3	519	319	102	421	1246	0	1246	5854	1483	7337	9004
3	521	0	0	0	24651	0	24651	0	0	0	24651
3	523	0	0	0	3984	0	3984	0	0	0	3984
3	524	0	0	0	636	0	636	0	0	0	636
3	541	229	0	229	551	0	551	899	0	899	1679
3	542	0	0	0	1559	0	1559	0	0	0	1559
3	All	3479	1765	5244	75387	0	75387	10328	1855	12183	92814
Total		108943	39044	147987	239462	145	239607	83240	36758	119998	507592

Table 2.10–Number of Pacific cod lengths sampled in 1997, partitioned by gear (trawl, longline, pot), location (at sea or on shore), period (1=Jan-May, 2=Jun-Aug, 3=Sep-Dec), and area (see Figure 2.4).

Per.	Area	Trawl			Longline			Pot			Total
		Sea	Shore	Subtot.	Sea	Shore	Subtot.	Sea	Shore	Subtot.	
1	509	38483	13626	52109	24543	0	24543	7777	3755	11532	88184
1	513	266	125	391	14435	0	14435	0	0	0	14826
1	517	44025	10210	54235	20261	0	20261	7714	878	8592	83088
1	518	151	0	151	253	36	289	0	124	124	564
1	519	7715	0	7715	208	84	292	11396	13239	24635	32642
1	521	2840	0	2840	98957	0	98957	0	0	0	101797
1	523	14	0	14	6680	0	6680	0	0	0	6694
1	524	190	0	190	4979	0	4979	0	0	0	5169
1	541	6504	0	6504	9108	0	9108	1023	0	1023	16635
1	542	1127	0	1127	5208	0	5208	700	0	700	7035
1	All	101315	23961	125276	184632	120	184752	28610	17996	46606	356634
2	509	0	0	0	0	0	0	2735	548	3283	3283
2	512	0	0	0	0	0	0	120	0	120	120
2	513	156	0	156	0	0	0	100	323	423	579
2	514	55	0	55	0	0	0	0	0	0	55
2	516	0	0	0	0	0	0	195	0	195	195
2	517	24	0	24	0	0	0	2774	382	3156	3180
2	518	0	0	0	0	0	0	1251	0	1251	1251
2	519	0	0	0	0	0	0	2525	1671	4196	4196
2	521	40	0	40	0	0	0	2401	0	2401	2441
2	523	0	0	0	0	110	110	0	0	0	110
2	All	275	0	275	0	110	110	12101	2924	15025	15410
3	509	0	0	0	26758	0	26758	1202	0	1202	27960
3	512	0	0	0	139	0	139	0	0	0	139
3	513	0	0	0	18544	0	18544	0	0	0	18544
3	516	0	0	0	1303	0	1303	0	0	0	1303
3	517	0	0	0	29658	0	29658	1306	535	1841	31499
3	518	0	0	0	125	0	125	1396	165	1561	1686
3	519	0	0	0	1912	0	1912	5082	1986	7068	8980
3	521	0	0	0	57629	0	57629	0	0	0	57629
3	523	0	0	0	4521	0	4521	0	0	0	4521
3	524	0	0	0	3922	0	3922	0	0	0	3922
3	541	0	0	0	0	0	0	35	0	35	35
3	542	0	0	0	0	0	0	57	0	57	57
3	All	0	0	0	144511	0	144511	9078	2686	11764	156275
Total		101590	23961	125551	329143	230	329373	49789	23606	73395	528319